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PHOSPHORUS FILLINGS FOR MUNITIONS

Progress Report on Work Performed in the Period April 1 to

June 30, 1947, under Contract W-18-035-CWS-1318

Wilson Dam, Alabama

[redacted]

Tennessee Valley Authority
Chemical Engineering Department
Chemical Research and Engineering Branch
Chemical Research Division

PHOSPHORUS FILLINGS FOR MUNITIONS

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By

J. C. Brosheer, F. A. Lenfesty, and F. L. Ines

Wilson Dam, Alabama

Tennessee Valley Authority
Chemical Engineering Department
Wilson Dam, Alabama
July 30, 1947

Commanding Officer
CWS Technical Command
Building 330
Edgewood Arsenal, Maryland

Attention: Chief, Munitions Division

Gentlemen:

Transmitted herewith are six copies of the fourth quarterly progress report on our studies of phosphorus fillings for munitions. The report covers work performed under contract W-18-035-CWS-1318 during the period April 1 to June 30, 1947.

Very truly yours,

TENNESSEE VALLEY AUTHORITY

K. L. Elmore

K. L. Elmore, Chief
Chemical Research Division

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SUMMARY

In a continuation of the search for suitable binders for granulated white ~~phosphorus~~ p in fillings for munitions, several additional commercial casting resins were tested. ~~Investigation of methods of preparation of~~ resins ~~from laboratory reagents~~ was discontinued.

A test for evaluation of the thermal stability of the experimental fillings in projectiles was devised and used. The method is based on the lateral shift of the center of gravity from the longitudinal axis of the filled projectile when the projectile is stored on its side at 65° C.

In tests of various bursting charges in M15 grenades, certain of the experimental fillings performed satisfactorily when exploded with M6A4D fuzes, M6A3 fuzes boosted with a small amount of a propellant powder, or EC powder ignited with M201 fuzes. Both M6A3 fuzes and a combination of powder from .30-'06 service rifle ammunition with M201 fuzes proved unsatisfactory as bursters.

Of the experimental phosphorus fillings subjected to firing tests, those in which the granulated phosphorus was bound with plaster of paris were the most promising. Fillings bound with Duralon, Palestic, and Thiokol LP-2 performed fairly well, but fillings bound with phenolic casting resins gave poor smoke screens.

Flame retardants, such as are used in permissible explosives to lower the temperature of combustion, appeared in preliminary tests to be worthy of further study as agents for improving the performance of the phosphorus fillings.

Plans for future work include additional firing tests on fillings that appear promising and attempts to prepare fillings composed of mixtures of white and red phosphorus.

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In the 3-month period covered by this progress report, additional commercial casting resins were tested as binders for granulated white phosphorus, and the efficacy of plaster of paris as a binding agent was explored further. A method was devised for determining the thermal stability of fillings comprising granulated phosphorus with various binders. The performance of the experimental fillings in M15 grenades was studied as a function of the type of burster. The following sections of the report present the details of the experiments and the plans for immediate future research on the project.

RESIN BINDERS FOR GRANULATED WHITE PHOSPHORUS

Since various commercial casting resins appeared superior to resins that could be concocted in the laboratory, preparation of binders from laboratory reagents was discontinued. Several grenades were filled with a mixture of granulated phosphorus and urea-furfural-citric acid laboratory resin; the filling deteriorated rapidly at 65° C., however, and the grenades were used in an exploratory investigation of bursting charges with results that are not comparable to the routine firing tests.

Commercial Resins

The commercial preparations listed in Table I form stable mixtures with granulated white phosphorus. The phenolic resins are liquid phenol-formaldehyde condensation products. In their commercial use as casting resins, they are hardened by heating them with the hardening agent at about 75° C. for periods from several minutes to a few hours. They become sufficiently rigid for use as binders in phosphorus fillings at room temperature, however, but the time required for the hardening is longer than that necessary at elevated temperatures. At room temperature the hardening is practically complete in periods from several hours to a few days.

TABLE 1

Commercial Resins Used as Binders in Phosphorus Fillings

Resin	Manufacturer	Hardening agent Mfr's. designation	Hardening agent %[a]	Setting characteristics, hr. Workable period	Initial set	Final set
Phenolic type						
Baker No. 100,972	Baker Oil Tools, Los Angeles, Cal.	Catalyst 100,085	10	3	7	24-48
			12	3	7	24
			15	3	7	24
Catabond 400	Catalin Corp., New York, N. Y.	Accelerator No. 8	9	<1	16	40
Durez 7421A	Durez Plastics & Chemicals, N. Tonawanda, N. Y.	Accelerator 7422	8	5	6	8-18
			10	3	4	6-18
			12	2	2.5	4-18
Marblette No. 69	Marblette Corp., Long Island City, N. Y.	Hardener No. 342	10	1	24	48
			12	1	24	48
			15	1	24	48
Syncast No. 138	Snyder Chem. Corp., Bethel, Conn.	Accelerator D	7	5	-	24
Synvaron No. 675	Rhodes Industrial Corp., E. Hampton, N. Y.	Hardener PA	10	1	5	21
Furane type						
Duralon 30	U. S. Stoneware, Akron, O.	Activators F	7.2	24	-	72
		G	3.0			
Urea-formaldehyde type						
Palestic	Palestic Corp., Chicago, Ill.	Palestic	53	1	-	1.2
		Factor	3.5			
		Water	33			
		Palestic	53	same as plaster of paris		
		Factor	3.5			
		Water	33			
		Plaster of paris	100			
Thiokol LP-2	Thiokol Corp., Trenton, N. J.	PbO_2	7.5	very short		
		Furfural	20	24		48
		Formic acid	4			

[a] On basis of weight of resin.

Duralon apparently is the only furano-type casting resin that is produced commercially. Its properties are similar to those of the phenolic casting resins, except that it is somewhat slower to harden at room temperature.

Palestic is a stabilized, water-soluble, liquid urea-formaldehyde condensation product. It was developed as a strengthening agent for plaster of paris casts. In practice, Palestic and its "factor" are added to the water-plaster mixture, and the resultant mixture behaves much the same as ordinary plaster. The dried cast is said to be stronger and more resistant to chipping than plaster alone.

Thiokol LP-2 is described as a low-molecular polysulfide polymer having reactive mercaptan terminals and side groups capable of further polymerization and cross-linkage. Mixtures of Thiokol LP-2 with lead peroxide ~~are quite~~ stiff and somewhat difficult to mix with granulated white phosphorus. Because of the possible reaction of the peroxide with white phosphorus, the mixtures are considered somewhat hazardous, although small batches have been prepared without mishap. The polymer cures readily with furfural and formic acid, but further investigation will be required to determine the optimum proportions of these reagents.

Modifications of Binders

Although plaster of paris casts may be strengthened by the incorporation of Palestic and its factor in the initial mixture, incorporations of urea-formaldehyde and urea-furfural resins failed to impart any desirable characteristics to plaster casts.

Emulsions of white phosphorus in water can be prepared with polyvinyl alcohol as the emulsifying agent. Emulsions containing as much as 80 per cent of molten white phosphorus as the disperse phase can be prepared, but the emulsions break on standing at room temperature. A cold emulsion breaks rapidly when heated above the melting point of phosphorus. It was found, however, that fillings with desirable burning properties could be prepared from granulated phosphorus, plaster of paris, and a polyvinyl alcohol-water-phosphorus emulsion that contained about 50 per cent phosphorus.

Hydrated salts are commonly incorporated into explosives to reduce the temperature of combustion. Among such salts are gypsum and other hydrated sulfates, alums, borax, and various ammonium salts. The uniformly good performance of plaster of paris fillings led to the assumption that the excess water added to make the initial mix workable may have reduced the pillaring by decreasing the temperature of combustion. On this assumption, flame retardants were added to a filling in which Marblette, a phenolic casting resin, was used as a binder. The flame retardants, borax, potassium alum, ammonium oxalate, and epsom salt, brought about a marked improvement in the performance of the fillings. Further work showed that Duralon and Thiokol LP-2 apparently withstood the incorporation of flame retardants better than did the phenolic resins. Work on the effect of flame retardants on the performance of phosphorus fillings is being continued. Ammonium, aluminum, and iron chlorides will be included in future tests.

THERMAL STABILITY TESTS

It is assumed that the exudation test currently used to determine the thermal stability of PWP is not applicable to rigid fillings of the type prepared by TVA. It is assumed also that the major adverse effect of thermal instability of otherwise rigid fillings would be the lateral shift of the center of gravity of the filled projectile from the longitudinal axis when the projectile was stored in a horizontal position under tropical conditions. To measure this shift in the center of gravity, a rigid steel track was constructed and the parallel members were ground to true straight edges. Unbalance of the filled missile was measured by determining the weight, suspended from a string wrapped around the missile, necessary to maintain the missile at rest 90° from its natural rest point on the level track. Since the radius and weight of the missile were known, the distance of the center of gravity from the longitudinal axis was calculated readily.

In preliminary tests of the method, sections of 57-mm. glass tubing, sealed at one end, were filled about two-thirds full of mixtures of granulated phosphorus with Thiokol LP-2. The resin was cured with furfural and formic acid. The tubes were closed with rubber stoppers through which passed small-bore glass tubing to release any pressure developed in the containers. When the fillings had hardened, the tubes were placed horizontally in a water bath at 65° C. for 24 hours, after which they were removed and allowed to cool in the same position they had occupied in the bath. After the unbalance of each tube had been measured, the exuded phosphorus that had collected in the empty space between the filling and the rubber stopper was cut out and weighed. The exuded phosphorus accounted for about one-half of the unbalance of the tubes. The data were insufficient, however, to permit estimation of the distribution of the retained phosphorus in the body of the filling.

Similar thermal stability tests were made on M15 grenades containing various experimental fillings. The grenades contained 225 cc. of filling, which occupied about 90 per cent of the free space in the grenade. In assembling the grenades, the male threads of the burster wells were coated with a heavy-duty grease. The grenades were placed on their sides in an oven at 65° C. Thirty per cent of the grenades so heated leaked phosphorus around the threads of the burster well, usually within 1 hour. The leaking grenades were removed from the oven immediately and allowed to cool in a horizontal position. The other grenades were removed at the end of 8 hours and also were cooled in the same position they had occupied in the oven. The results of the tests are shown in Table II. It is apparent that the change in distribution of the phosphorus in the grenades occurs in less than 8 hours of exposure to tropical storage conditions. Subsequent heating of some of the grenades at 65° C. for 7 hours while standing on their bases resulted in reduction of the unbalance practically to zero, from which it is concluded that thermal instability of fillings of the type prepared in the present study is due to movement of molten phosphorus by gravity flow, and that the center of gravity of the filled munition may be restored substantially to its original position by heating while in the upright position.

From the data in Table II it is concluded that, of the fillings tested, only those in which the binders were Catabond, Palostic without water, ~~and~~ Thiokol LP-2 are thermally unstable to a degree that would affect the ballistics of the projectile. Comparison of J4A and J5A, which were cured with 4 per cent formic acid, with J3A, cured with 2 per cent formic acid, indicates, however, that suitable methods of curing may yield a thermally stable Thiokol LP-2 binder. The unbalance of the PWP grenade was approximately what would be expected if it is assumed that the entire charge behaves as a liquid at 65° C.

All the grenades that had been subjected to thermal stability tests were subsequently fired in comparison with unheated grenades. There was no apparent difference in the performance of heated and unheated grenades.

TABLE II

Thermal Stability Tests of Phosphorus Fillings in M15 Grenades

No.	Filling: Binder	Filling: Wt., g.	Total wt. of grenade, g.	Time heated, hr.	Wt. to balance, g.	Shift of center of gravity, mm.: Total	Shift of center of gravity, mm.: Filling
C2A	Plaster of paris	403	742	8	6	0.2	0.5
				16	7	0.3	0.5
LC4A	PVA-plaster[b]	364	701	8	8	0.3	0.7
				16	10	0.4	0.8
E1A	Duralon	312	636	8	9	0.4	0.9
				16	8	0.4	0.8
E1B	Duralon	329	643	1[a]	9	0.4	0.9
D1A	Durez	307	631	8	18	0.9	1.8
D1B	Durez	329	643	1[a]	21	1.0	2.0
K2B	Catabond	321	649	1[a]	32	1.5	3.0
K2C	Catabond	341	669	1[a]	21	0.9	1.9
M1A	Marblette	329	661	8	2	0.1	0.2
M2A	Marblette	347	689	1[a]	7	0.3	0.6
M2B	Marblette	369	714	1[a]	4	0.2	0.3
P1C	Palestic[c]	351	697	8	4	0.2	0.3
P2C	Palestic[d]	357	680	8	42	1.9	3.7
PC1D	Palestic-plaster[e]	395	739	8	5	0.2	0.4
J3A	Thiokol LP-2[f]	302	64[illegible]	8	69	3.2	6.9
				16	69	3.2	6.9
J4A	Thiokol LP-2[g]	335	673	8	16	0.7	1.4
				16	20	0.9	1.8
J5A	Thiokol LP-2[h]	328	670	8	25	1.1	2.3
				16	26	1.2	2.4
J6A	Thiokol LP-2[i]	329	669	8	25	1.1	2.3
J7A	Thiokol LP-2[j]	356	698	8	42	1.8	3.5
PWP4	Plasticized WP[k]	250	[illegible]	8	49	2.4	5.0
				16	52	2.6	6.2

[a] Grenade leaked phosphorus.
[b] Polyvinyl alcohol-water-phosphorus emulsion used to supply water to set plaster.
[c] Palestic rosin, factor, and water.
[d] Palestic rosin and factor; no water.
[e] Plaster of paris and Palestic mixture.
[f] Cured with 20 per cent furfural, 2 per cent HCOOH.
[g] Cured with 30 per cent furfural, 4 per cent HCOOH.
[h] Cured with 20 per cent furfural, 4 per cent HCOOH.
[i] Linseed oil used as plasticizer.
[j] Same as J6A, but with fine granulated P.
[k] Supplied by Edgewood Arsenal.

FIRING TESTS

In previous firing tests the experimental fillings were evaluated on the assumption that the smoke generated in the burst of the munition was largely wasted and that the ideal performance would be the production of the minimum amount of cloud at the burst and the scattering of the maximum amount of relatively large pieces of filling which would burn on the ground to produce a screening trail. Mr. Kracke, in his visit to Wilson Dam on May 5, 1947, stated, however, that the ideal phosphorus filling would produce an instantaneous cloud that would hug the ground and not be wasted at higher altitudes. On the basis of informal talks with Mr. Kracke, it is concluded that ideal performance may be described as the production of a screening cloud, generated almost simultaneously with the burst, that screens an area from ground level to a height of about 12 feet. Pillaring that results in ascent of smoke more than 12 feet above ground is wasteful, and particles of filling that burn so slowly that they do not maintain the original cloud are likewise wasteful.

The firing tests covered by the present report were made on a large, fairly level fill comprising wastes from Nitrate Plant No. 2. Firing usually was started at about 0900 hours and continued through 1130 hours. At the beginning of each morning's firing the weather was fairly cool (70° F.) and the wind velocity was below 4 miles per hour. As the morning advanced, however, the temperature rose to about 95° F., and the wind increased both in velocity (to 12 miles per hour as a maximum) and in gustiness. It was observed that, under the best conditions (cool, relatively still morning), screening smokes persisted for a maximum of about 15 seconds in most shots. As the weather conditions became worse, either the wind carried the smoke rapidly out of the range of effective observation, or thermal ~~updrafts~~ accentuated the pillaring effect of the burst. In the evaluation of shots fired under these unfavorable conditions, allowance was made for the adverse effect of high winds and of thermal updrafts. Future firing tests will be made under more suitable conditions.

Firing and Observation Procedures

The armed grenade was inserted, base first and up to its shoulder, into a short length of standard 2.5-inch pipe. A loop of wire was passed around the top of the burster well under the striker housing and attached to a stiff wire hook anchored in the ground. The safety pin was then withdrawn, and the pipe containing the grenade was laid on the ground. The grenade was fired by pulling the retaining pipe from the grenade with a rope that extended to the observation point. All grenades were thus lying on their sides on the ground when the burster exploded.

Observations were made from a point 50 yards from the burst, and attempts were made to keep the line from the burst to the observation point at right angles to the wind. Notes were made of the diameter of the burst (total distribution of fragments of the filling normal to the line of observation), relative amount of pillar, time of persistence of screening smoke, ~~density~~ of screening smoke, type of rupture of grenade case, and amount of filling remaining in the burst case. A camera (Kodak 35, with Lifa Omnicolor filter, loaded with Kodak Super XX film) was mounted at the observation point, and pictures were taken of the burst and of the smoke 5 seconds and 10 seconds after the burst.

Pictures of the various types of smokes produced in the firing tests are shown in Figures 1 and 2. All the smokes shown in Figure 1 are rated as satisfactory. The cloud shown in C2F is considered of the desirable type, although at 10 seconds the screen is beginning to thin at the left-hand side near the ground. The semi-columnar type of cloud shown in C2A is obtained more frequently than the type shown in C2F. The screen shown in M5B is the best that was obtained in the series covered in this report; the screen persisted for 25 seconds. The screen shown in E1B is considered little better than fair. Grenades E1A and J8B were fired in a 6-mile wind.

All the smokes shown in Figure 2 are considered unsatisfactory. Too much smoke is wasted in the pillar in D1E, whereas A4A illustrates an extremely rapid dissipation of smoke, presumably in a thermal updraft. An undesirable characteristic, frequently encountered, of a slender column of smoke with little screening effect is illustrated by E1C and D1D. The burst in PWP3 was obtained when a grenade containing PWP was burst with EC powder; this is the only grenade burst similar to the characteristic bursts obtained when fillings in glass beakers were exploded with firecrackers. The smoke in both PWP3 and PWP4 is too thin for effective screening.

Effect of Type of Burster

The performance of M6A4D fuzes was satisfactory with all the experimental fillings. Of the grenades exploded with M6A4D fuzes, 80 per cent were torn, 12 per cent were cupped, and the rest were split or lantern burst.

The bursting force of M5A3 fuzes was too weak for satisfactory performance with any of the experimental fillings. When these fuzes were boosted with 2 cc. (2 grams) of .30-'06 powder, however, the cases were torn consistently by the explosion, and the performance was comparable to that of grenades burst with M6A4D fuzes.

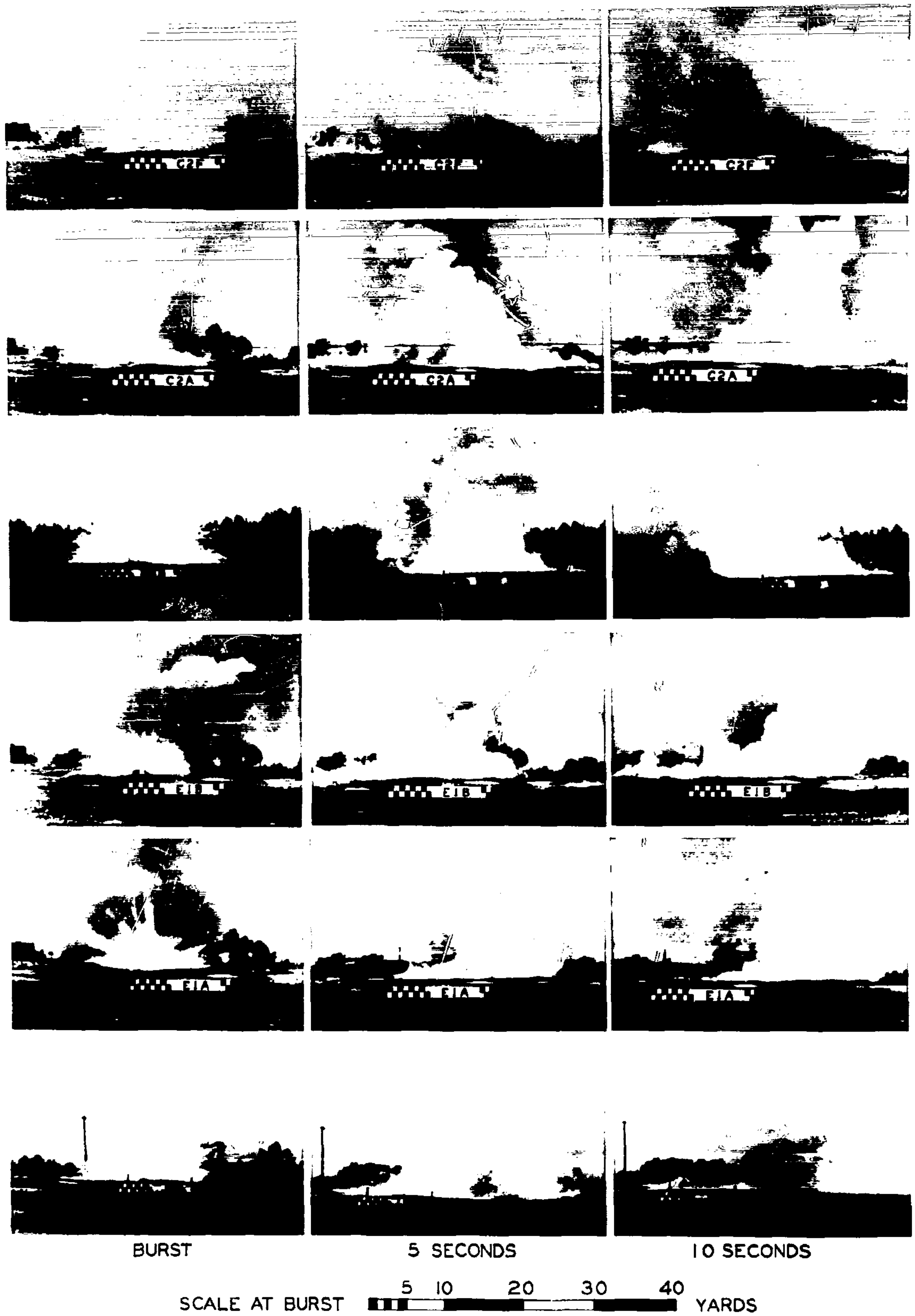

FIGURE 1
SATISFACTORY SMOKES PRODUCED BY PHOSPHORUS FILLINGS IN M15 GRENADES

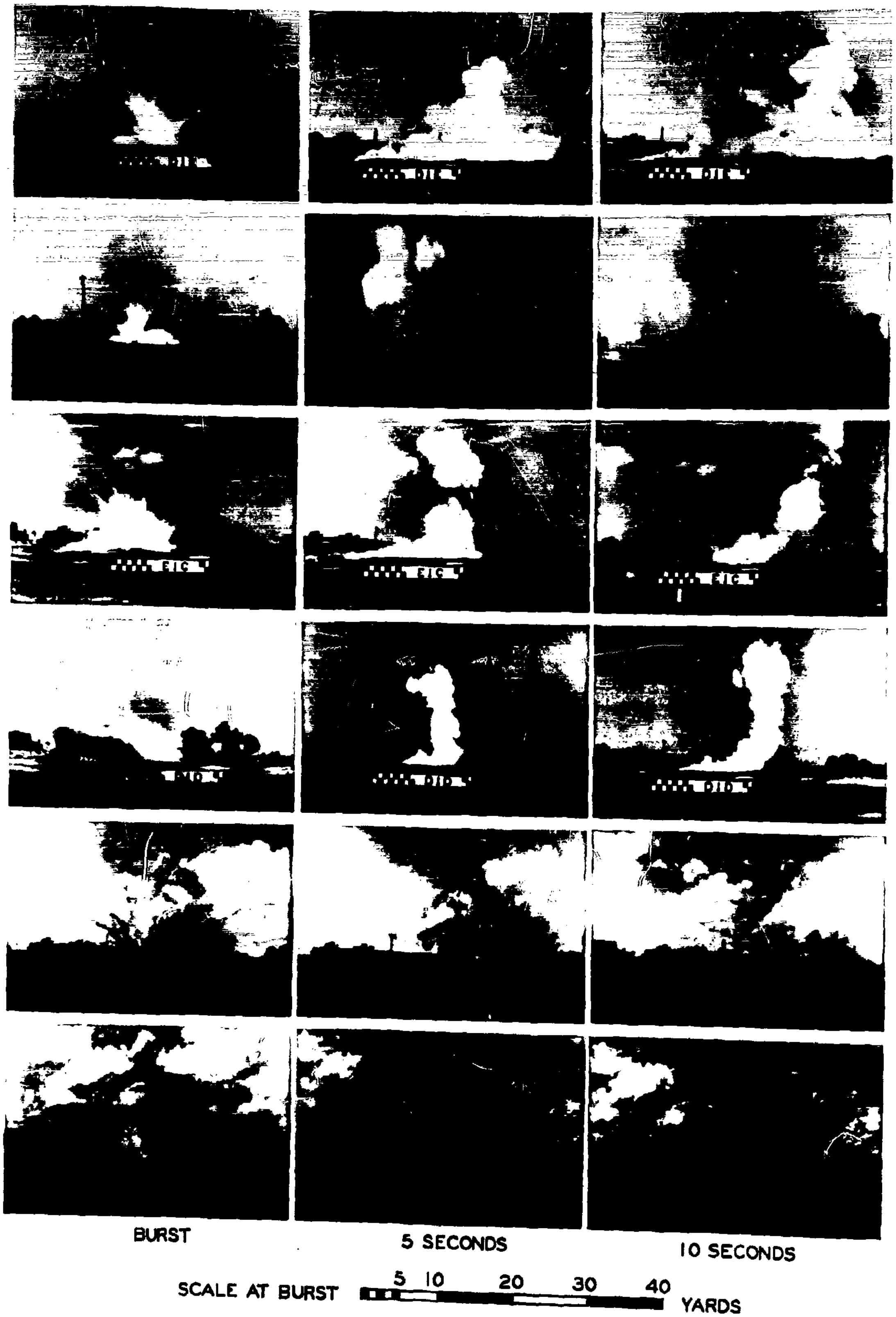

FIGURE 2
UNSATISFACTORY SMOKES PRODUCED BY
PHOSPHORUS FILLINGS IN M15 GRENADES

A combination of EC powder with M201 fuzes performed satisfactorily, but 8 cc. (3 grams) of the powder was required for proper functioning. With this charge, 74 per cent of the cases were torn and 22 per cent were lantern burst by the explosion.

The powder from U. S. Army .30-'06 service rifle cartridges, ignited with M201 fuzes, was less satisfactory as a bursting charge than EC powder. When 8 cc. (8 grams) of .30-'06 powder was used as the bursting charge, 40 per cent of the cases were torn, 40 per cent were lantern burst, and 20 per cent were cupped by the explosion.

Incidentally, 54 per cent of all grenades that were torn by the bursting charge produced good smokes, 23 per cent produced fair smokes, and 23 per cent produced poor smokes. On the other hand, 50 per cent of the smokes produced by lantern-burst, split, or cupped cases were rated as poor.

Performance of Fillings

All the experimental fillings prepared by TVA were mixtures of granulated white phosphorus with a fluid binder which subsequently set to a rigidly solid mass. Since all the fillings contained granulated phosphorus, they are identified in the following discussion by the binder used in their preparation.

Massive phosphorus in M15 grenades performed too erratically to be a satisfactory standard for comparison with other fillings. Pillaring usually was marked, and the smoke usually formed a slender rising column that had little screening value. Oddly enough, particles of massive phosphorus that were scattered by the explosion often burned for as long as 2 minutes after the burst, which compared favorably with the burning time of particles of fillings prepared with binders, but the smoke generated by these burning partic'es was not dense enough to have value as a screen.

Four grenades containing PWP were obtained from Edgewood Arsenal and were fired in comparison with experimental fillings prepared by TVA. All four PWP grenades produced thinner and less screening smoke than was considered satisfactory. The smokes from two of these grenades, PWP3 and PWP4, are shown in Figure 2. Grenade PWP3 was exploded with EC powder, and the appearance of the burst indicates that the plastic PWP was extruded through the ruptured case by the propellant powder. This case, however, was torn by the bursting charge. Grenade PWP4 was exploded with an M6A4D fuze; whereas this grenade performed better than any of the other PWP grenades, the smoke produced was too thin to be an effective screen.

Phenolic Fillings: The performance of phenolic fillings was poor. In general, the smokes tended to form rising columns similar to those shown in D1E and D1D in Figure 2. Both these fillings were prepared with Durez casting resin, and the pictures are extreme examples of undesirable performance. Catabond resin made better fillings, in general, than did either Baker, Durez, or Marblette resins, but the number of grenades of each type tested was too small for conclusive comparison. As a whole, however, the phenolic binders were less promising than other binders.

Duralon Fillings: As shown by E1A and E1B in Figure 1 and E1C in Figure 2, Duralon fillings performed fairly well.

Palestic Fillings: Fillings bound with Palestic resin alone showed sufficient promise to warrant further investigation. Fillings in which Palestic and plaster of paris together were used as the binder performed poorer than did plaster of paris fillings that contained no Palestic.

Thiokol LP-2 Fillings: The Thiokol LP-2 fillings were cured with furfural and formic acid. Fillings cured with 20 per cent furfural and 4 per cent formic acid performed well enough to indicate that proper curing of Thiokol LP-2 may result in a satisfactory filling. Fillings cured with 20 per cent furfural and 2 per cent formic acid performed erratically, probably because of nonuniform curing in the presence of the small amount of acid. Fillings cured with 30 per cent furfural and 4 per cent formic acid performed poorly, and modification of the binder in these fillings by incorporation of linseed oil or ethylene glycol was of no apparent advantage.

Plaster of Paris Fillings: The performance of fillings bound with plaster of paris was consistently better than that of any of the other fillings. Grenades C2F and C2A in Figure 1 contained plaster fillings. Mixtures in which the water required to harden the plaster of paris was supplied by a polyvinyl alcohol-water emulsion of phosphorus containing 50 per cent phosphorus also performed very satisfactorily.

Flame Retardants: Plaster of paris fillings that are allowed to set in a closed container remain moist with the excess water that is added to form an initially fluid, workable mixture. The consistently good performance of these fillings led to the assumption that the excess water in the mixture may have reduced the temperature of the initial combustion when the grenade was exploded, and so reduced the amount of pillar.

To test the effect of substances which might be expected to reduce the temperature of combustion, several grenades were filled with granulated phosphorus which was covered with various liquids. When the phosphorus was covered with water, kerosene, or carbon tetrachloride, the grenades performed much like grenades filled with massive phosphorus, and much of the smoke was wasted in a pillar. When the phosphorus was covered with ethyl alcohol, the burst resulted in a small ball of smoke about 5 yards in diameter. Most of the granules were scattered unburned on the ground, and about 5 seconds elapsed before they ignited. This behavior is an example of the well-known tendency of certain organic liquids and their vapors to inhibit the oxidation of phosphorus.

Several Marblette fillings were prepared in which the binder was modified by the incorporation of 15 per cent of borax, 20 per cent of potassium alum, 15 per cent of ammonium oxalate, or 20 per cent of epsom salt. All these fillings performed well, in marked contrast to the poor performance of the unmodified Marblette filling. The filling modified with ammonium oxalate performed better than any other in this group; M5B in Figure 1 shows the smoke produced by one of those ammonium oxalate-Marblette fillings. It has since been found that both Duralon and Thiokol LP-2 apparently withstand incorporation of ammonium oxalate with less adverse effect on their physical properties than do any of the phenolic binders. Investigation of the effect of flame retardants on the performance of Duralon and Thiokol LP-2 fillings is being continued.

REVIEW OF RESULTS AND PLANS FOR FURTHER WORK

On the basis of both thermal stability tests and firing tests, fillings containing plaster of paris as the binder appear to be the best that have been prepared in the present study. Duralon and Palestic fillings also appear to have considerable promise, and Thiokol LP-2 fillings may be developed that will perform satisfactorily. The various phenolic casting resins do not appear promising, but all the experimental fillings will be subjected to additional firing tests under more suitable weather conditions before final conclusions are drawn.

A shipment of stirrer-granulated phosphorus, of particle size mostly between 50 and 80 mesh, has been received from Edgewood Arsenal, and various fillings containing this material will be prepared with the binders used in TVA experimental fillings. Since the jet-granulated phosphorus prepared at TVA is coarser (4 to 16 mesh) than the stirrer-granulated phosphorus, attempts will be made to increase the amount of phosphorus in the experimental fillings by mixing the two types of granules.

Mixtures of red and white phosphorus, such as are obtained by partial conversion of liquid white phosphorus to the red form, are promising fillings. Some work has been done on these fillings at Edgewood Arsenal and reported in T. D. M. R. No. 793 and in a report of test dated September 22, 1944, on project A5.2-4. Grenades filled with white phosphorus will be heated for various times at temperatures between 250° and 300° C. to convert various proportions of the white phosphorus to the red modification, and the treated grenades will be subjected to thermal stability tests and to firing tests.

From observations of the performance of phosphorus fillings in M15 grenades, it is concluded that test firings of experimental fillings in this munition should be conducted under suitable weather conditions. The optimum wind velocity appears to be 2 to 4 miles per hour; at lower velocities the smoke may tend to bunch up more than is desirable in tests, and all smokes may tend to appear to perform much alike. At higher velocities, even at 5 or 6 miles per hour, the wind may dissipate so rapidly the relatively small amount of smoke produced by a grenade that critical evaluation is impossible. Thermal updrafts from ground under strong sunlight, particularly in summer weather, apparently tend to accentuate markedly the pillaring of a smoke, hence, firing tests should not be conducted when the ground temperature is above about 80° F.

To obtain more uniform weather conditions during future firing tests, the tests will be conducted between dawn and the time, probably 0800 or 0900 hours in the summer, when the wind becomes stronger than is desirable and the ground begins to heat up in the sun. A standard smoke, which will be used to evaluate weather conditions in general, will be generated by dumping, from a small metal beaker about 3 feet above the ground, a standard amount (probably about 100 cc.) of liquid 80-20 phosphorus-sulfur eutectic on a metal plate large enough to prevent marked penetration of the liquid into the ground.

Test grenades will be fired in front of a line of posts, 12 feet high and 8 yards apart. These posts will be 18 inches wide and will be painted in alternate black and white 18-inch squares. Evaluation of the smokes will be made on the basis of integration of the product of the totally obscured area between ground level and the top of the 12-foot posts and the time of persistence of the smoke. Attempts will be made to correct to standard conditions each evaluation by applying correction factors, to be determined later, which will allow for wind velocity and for over-all weather conditions as evaluated by the standard smoke.